Ouantitative Splanchnology study on European Catfish (*Silurus glanis*) Raised in Recirculating Aquaculture Systems

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Abstract

European catfish (*Silurus glanis*) is a species with considerable economic potential in aquaculture due to its adaptability and superior meat quality. The development of intensive breeding technologies has allowed the increase of production efficiency, making this species a viable choice for recirculating aquaculture systems (RAS) that have increased significantly in recent years in Europe and beyond. The aim of the study was to highlight the anatomical peculiarities of the internal organs of European catfish raised in an intensive, indoor recirculating aquaculture system (RAS), examining both morphological characteristics and quantitative splanchnology. Five male catfish, aged 2 years and 10 months, were studied. Among the results obtained, it was noted that the fish raised in the RAS up to the age of slaughter did not accumulate perivisceral fat, and the segments of the digestive tract were reduced in size, likely due to a diet based on dry feed. Thus, it can be said that the intensification of European catfish production has led to notable changes in the structure and function of internal organs, particularly within the digestive system, as a result of the feeding regime based on granulated dry feed. The particularities observed especially in the digestive tract reflect the adaptive responses of the fish to the environmental conditions and rearing practices used in intensive aquaculture.

Keywords: European catfish, RAS, quantitative splanchnology, anatomy.

1. Introduction

The European catfish (*Silurus glanis* L.) is the largest freshwater fish species in Romania and one of the most widely distributed predatory fish in Eurasia. It inhabits large rivers, reservoirs, and stagnant water bodies, showing remarkable ecological adaptability to variable environmental conditions. Beyond its natural range, the species has long been maintained in captivity for both aquaculture production and stocking purposes [1, 2].

Traditionally, European catfish has been reared for more than a century in ponds across Central and Eastern Europe, mostly in polyculture with common carp (*Cyprinus carpio*). Such practices have ensured its continuous presence in managed systems and its availability on local markets [3, 4]. Studies on pond-based farming further confirm that *S. glanis* can be successfully reared alongside carp, benefiting from natural food resources and favorable ecological interactions [5]. Similarly, Pronina et al. [6] highlighted the adaptability, rapid growth, and high-quality flesh of the species, as well as the technological advances in reproduction and broodstock management that support its integration into carp farming systems.

In recent decades, the need for higher production efficiency and market demand has accelerated the shift towards intensive aquaculture technologies. The adoption of recirculating aquaculture systems (RAS), controlled feeding with formulated diets, and the use of heated or geothermal water have enabled the successful rearing of European catfish at high stocking densities, including under indoor

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conditions [7, 8]. Currently, countries such as France, the Czech Republic, and Hungary combine traditional pond practices with intensive systems, thereby enhancing overall production [7, 9].

Recent findings indicate that culture conditions have significant effects not only on growth but also on physiology and product quality [10]. Barbacariu et al. [8] reported differences between pond- and RAS-reared catfish in terms of somatic indices, flesh composition, antioxidant enzyme activity, and intestinal microbiota, while Hallier et al. [11] demonstrated that farming environment can also affect flesh colour and texture. These results highlight that intensive rearing induces complex physiological and biochemical adaptations. Moreover, previous studies have shown that feeding formulated pellet diets and maintaining fish under high-density conditions can lead to structural and functional modifications of visceral organs, particularly within the digestive system [12, 13].

These observations support the relevance of studying the internal anatomy of European catfish in intensive aquaculture. The present work aims to investigate the morphological and quantitative features of the visceral organs of *Silurus glanis* reared in a recirculating aquaculture system, using quantitative splanchnology as a methodological approach.

2. Materials and methods

Experimental site and rearing system. The research was conducted during the spring of 2024 at the Fish Farm of the Didactic Station, University of Life Sciences "King Mihai I" from Timișoara, Romania. The experimental facility employed a RAS consisting of four 18 m^3 tanks.

Biological material and feeding. European catfish (*Silurus glanis*) were reared under intensive conditions following farm-specific protocols for the species, based on the highly intensive rearing technology developed at the Didactic Station. The main physico-chemical water parameters were monitored daily and remained within the optimal range for *S. glanis*, as documented in specialized literature [1]. Fish were fed exclusively with SUPREME 10 granulated compound feed (AlltechCoppens, Germany), administered ad libitum using FIAP-type semi-automatic belt feeders.

Sampling procedure. Five clinically healthy male European catfish, aged 2 years and 10 months, reared exclusively in the RAS, were randomly caught from the tanks. Selection of males was based on morphological sexing and the requirement for uniformity within the sample group. Fish were stunned prior to dissection using a FIAP Mini #1986 electric stunner (Germany).

Before dissection, biometric measurements were recorded for each specimen, including: total length (L), standard length (l), head length (L_head), snout length (L_snout), tail length (L_tail), maximum body height (H), body thickness (G), predorsal distance (DpD), preventral distance (DpV), preanal distance (DpA), and body mass (BM). Measurements followed standard ichthyological protocols [14].

From these values, body indices were calculated as follows:

$$Ip = l / H$$

where: Ip = profile index, l = standard length (cm), and H = maximum body height (cm).

$$K = (BM * 100) / l^3$$

where: K = Fulton’s condition factor (fatness index), BM = body mass (g), and l = standard length (cm).

Immediately after evisceration, carcass weight was recorded for slaughter yield determination. Biometric assessments were performed using an ichthyometer, measuring tape, and a precision scale (±1 g). Data were systematically recorded and subjected to statistical analysis using Microsoft Excel to obtain mean values and dispersion indices, enabling a comprehensive characterization of the fish batch.

Anatomical and splanchnological analysis. Following biometric evaluation, fish were dissected using a standard dissection kit (scalpel, surgical scissors, haemostat, and forceps). Internal organs were examined anatomically and topographically, excised (Figure 1), and measured to determine their primary dimensions. Quantitative splanchnology was applied to assess organ morphology and proportionality within the visceral complex.

Figure 1. One of the catfish specimens with excised organs prepared for quantitative splanchnology analysis

3. Results and discussion

Biometric Study of European Catfish.

Immediately after electrical stunning, biometric analysis was performed on the studied specimens. The main body dimensions were measured, and the data were statistically processed (Table 1).

The average total length of the catfish was 62.66±2.06 cm, while the maximum body height averaged 11.48±0.33 cm, resulting in a mean profile index of 5.46. The mean body mass prior to evisceration was 1.72±0.16 kg.

The biometric values recorded in this study reflect the good growth performance of *Silurus glanis* reared under intensive RAS conditions. The profile index (5.46) is consistent with the elongated body conformation typical of the species and indicates a uniform morphological structure within the analysed batch. Such results are in line with previous reports, which emphasized the morphological stability of *S. glanis* when reared under standardized aquaculture conditions [3, 9].

The Fulton condition factor (K=0.88) confirmed that the fish were in satisfactory nutritional and maintenance status. When compared with literature data, it appears that the condition factor of RAS-reared fish is higher than that of wild populations from the Prut River (0.82), but slightly lower than that of catfish reared in ponds (0.91) [4]. This pattern suggests that controlled feeding regimes and stable water quality in intensive systems ensure better maintenance than natural habitats, yet certain ecological factors in pond farming-such as lower stocking densities or access to natural food items-may further enhance energy accumulation and fat deposition. Havasi et al. [9] similarly observed that feeding regime significantly influenced growth performance and condition indices in *S. glanis*.

Table 1. Biometric data of male European catfish in the study group (n = 5)

Specification	Total length (cm)	Standard length (cm)	Head length (cm)	Snout length (cm)	Tail length (cm)	Maximum body height (cm)	Body girth (cm)	Predorsal distance (cm)	Preventral distance (cm)	Preanal distance (cm)	Body weight (cm)
Mean	62.66	58.10	11.98	2.66	39.20	11.48	29.06	17.42	21.10	24.90	1.72
SD	4.60	4.81	0.68	0.56	3.02	0.73	1.69	1.91	1.84	2.14	0.35
SEM	2.06	2.15	0.30	0.25	1.35	0.33	0.75	0.86	0.82	0.96	0.16
CV	7.34	8.27	5.67	21.03	7.71	6.34	5.81	10.99	8.72	8.58	20.47
SEM%	3.28	3.70	2.54	9.41	3.45	2.84	2.60	4.92	3.90	3.84	9.16

The calculated slaughter yield of 88.37% represents a particularly high processing efficiency. Such values are superior to those generally recorded for cyprinids and comparable or even higher than those of other intensively reared carnivorous fish species. From an economic perspective, this highlights the advantage of European catfish as an aquaculture species, since a higher proportion of edible carcass directly increases market value and processing profitability. Simeanu et al. [4] also reported comparable results, emphasizing the consistently high flesh yield of *S. glanis*.

Taken together, the biometric results demonstrate that *S. glanis* performs well under super-intensive RAS conditions, maintaining a favorable condition factor and achieving a high carcass yield. These findings provide a solid basis for further analysis of visceral organs, as body growth patterns and condition are directly linked to morphological and functional adaptations at the splanchnological level.

Anatomical and Quantitative Splanchnology. Dissection of the abdominal cavity revealed clearly identifiable organs, with all specimens presenting very limited perivisceral adipose tissue. This facilitated the localization and assessment of the heart, liver, spleen, stomach, intestine, swim bladder, gonads, and kidneys (Figures 2-4).

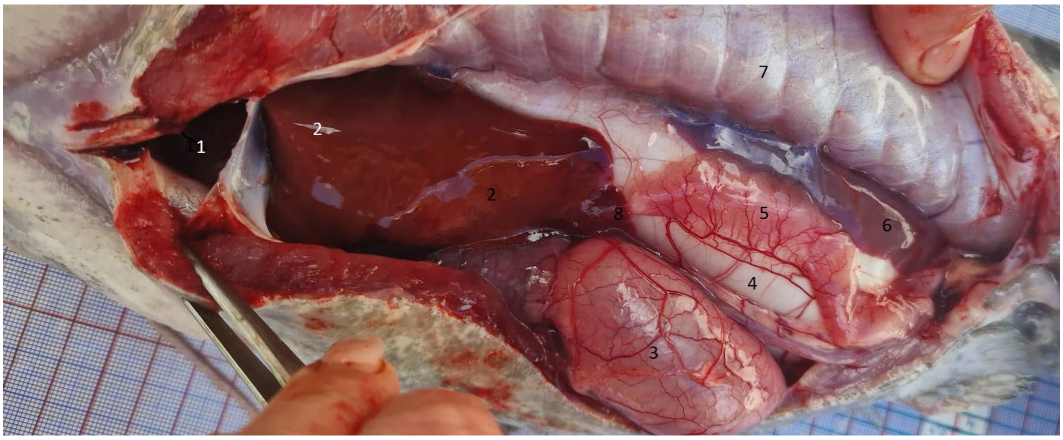


Figure 2. 1-pericardial cavity; 2-left lobe of the liver; 3-stomach; 4-swim bladder; 5-testicle; 6-kidneys; 7-abdominal wall; 8–spleen

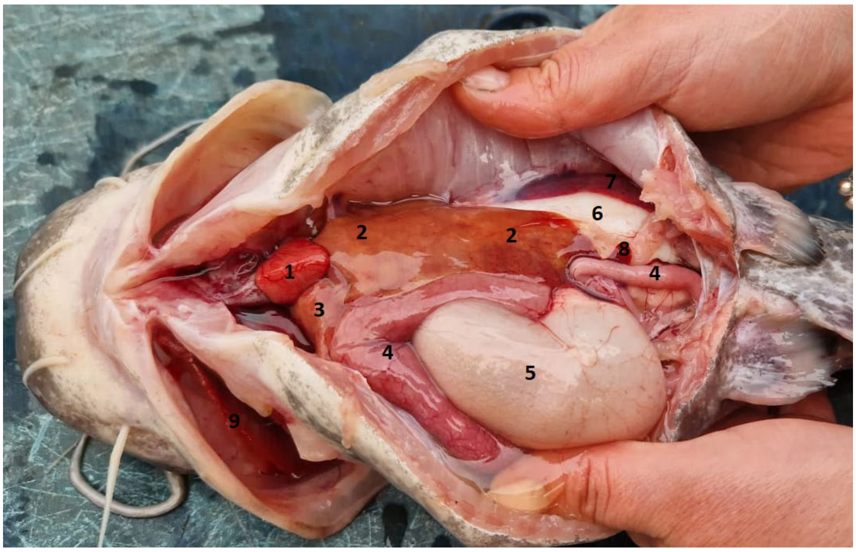


Figure 3. 1-heart; 2-left lobe of the liver; 3-right lobe of the liver; 4-intestinal loops; 5-stomach; 6-swim bladder; 7-kidneys; 8-spleen; 9–gills

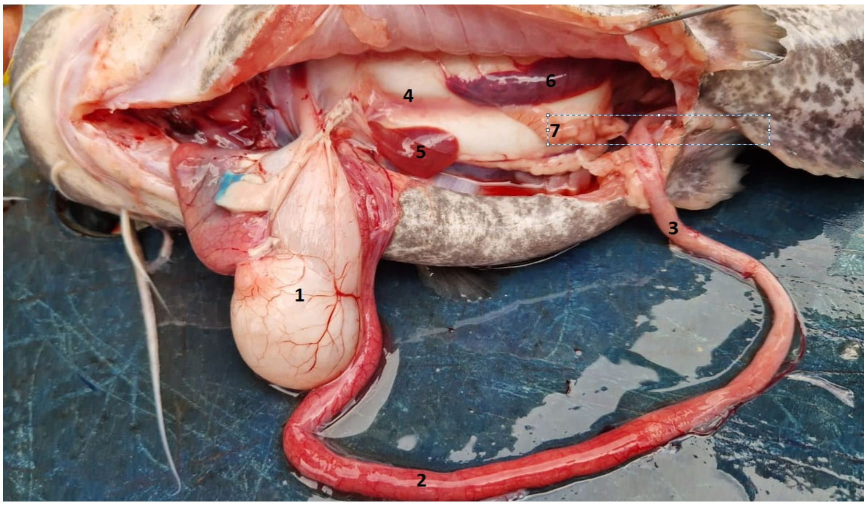


Figure 4. 1-stomach; 2-middle intestine; 3-hind intestine; 4-swim bladder; 5-spleen; 6 - kidneys; 7–gonads

The digestive tract of *Silurus glanis* shows several structural features related to its carnivorous diet. However, because the studied fish were fed exclusively with granulated compound feeds, certain organs, particularly the stomach, displayed relatively reduced dimensions compared to what is typically reported for wild ichthyophagous individuals. *The pharynx* had a complex structure, with gill lamellae on the convex side of the first four gill arches and short, strong rakers on the concave side (Figure 5). The average pharynx length was 5.54±0.34 cm.

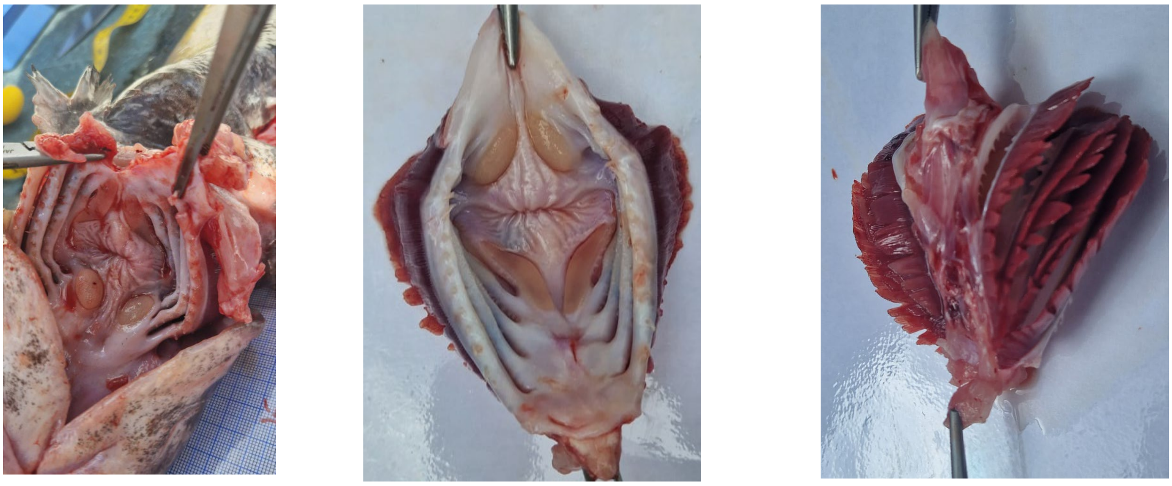


Figure 5. The pharynx in European catfish. The branchial arches with branchial spines on their concave side (left and middle) and with gills on the convex side

The esophagus appeared as a short tubular organ with longitudinal folds, measuring on average 2.50±0.08 cm in length, 1.06±0.09 cm in diameter, and weighing 2.62±0.40 g. *The stomach* was sac-shaped, with well-differentiated cardiac and pyloric regions, the body being the most developed.

The body of the stomach is the most developed region; however, in the studied specimens, it was not as large as expected for a ichthyophagous fish. This observation is correlated with the feeding regime, as the fish were exclusively fed granulated compound feeds. In the studied fish, the average volumetric capacity was 56.00±7.48 ml, and the mass was 16.60±2.69 g (Figure 6).

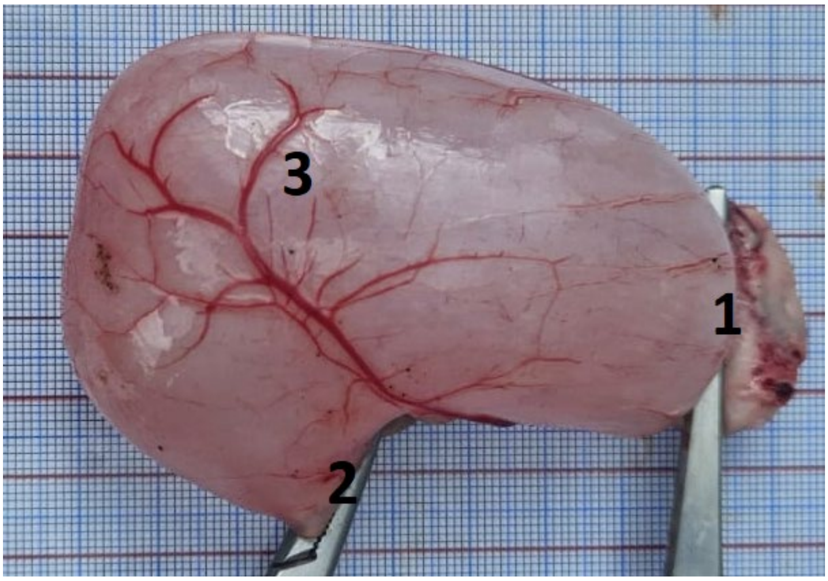


Figure 6. The stomach in European catfish; 1–cardia; 2–pylorus; 3–body of the stomach

Nevertheless, the reduced stomach dimensions observed in the present study suggest a functional adaptation to feeding on compound granulated diets, which differ substantially from the natural ichthyophagous diet of wild catfish. Similar observations were reported by Barbacariu et al. (2023) [8], who demonstrated that fish reared in RAS systems show physiological and microbial changes in the digestive tract compared to pond-reared individuals.

The intestine appears as a tubular organ, significantly shorter compared to the intestines of other fish species, a characteristic attributed to its carnivorous diet (Figure 7).

Figure 7. Gut length in relation to body length

In the studied specimens, the intestinal length (64.36±2.64 cm) was only 1.03 times greater than the total body length (62.66±2.06 cm).

Three regions with different diameters could be distinguished along the intestine: anterior (1.72±0.07 cm), middle (0.92±0.03 cm), and posterior (1.01±0.14 cm) (Fig. 8).

The intestinal volumetric capacity is relatively high; in the studied specimens, it averaged 56.50±5.54 ml (Table 2).

Figure 8. The stomach and the anterior region of the intestine; 1 – stomach; 2 – cardia; 3 – pylorus; 4 – anterior intestine; 5 – middle intestine

Table 2. Data from quantitative splanchology study of the digestive tract (n = 5)

Specification		Mean	SD	SEM	CV	SEM%
Pharynx length (cm)		5.54	0.75	0.34	13.60	6.08
Esophagus length (cm)		2.50	0.19	0.08	7.48	3.35
Ø Esophagus (cm)		1.06	0.21	0.09	19.56	8.75
Esophagus mass (g)		2.62	0.89	0.40	34.07	15.24
Stomach volumetric capacity (ml)		56	16.73	7.48	9.88	13.36
Stomach mass (g)		16.60	6.02	2.69	36.29	16.23
Intestine length (cm)		64.36	5.90	2.64	9.17	4.10
Intestine volumetric capacity (ml)		56.50	12.39	5.54	21.93	9.81
Intestine mass (g)		21.60	4.22	1.89	19.53	8.74
Ø intestine (cm)	Anterior section	1.72	0.15	0.07	8.62	3.86
	Median section	0.92	0.08	0.03	8.24	3.69
	Posterior section	1.01	0.32	0.14	31.78	04.21

The short length of the esophagus and intestine relative to total body length, together with the sac-like stomach, are consistent with the carnivorous feeding habits of the species [12]. Our finding aligns with the results of Pronina et al. [6], who emphasized that the digestive morphology of *S. glanis* is strongly correlated with its feeding ecology. The relatively large volumetric capacity of the intestine observed in the present study may reflect adjustments to the continuous feeding regime typical of intensive aquaculture systems, where smaller rations of pelleted feed are consumed throughout the day.

The liver large, bilobed organ located caudally to the heart, with the left lobe larger than the right (Table 3), (Figure 9). The mean liver mass was 29.20±2.17 g with the gall bladder, and 26.00±3.39 g without.

Table 3. Liver quantitative splanchnology data (n = 5)

Specification	Left lobe length (cm)	Right lobe length (cm)	Left lobe width (cm)	Right lobe width (cm)	Liver mass with gall bladder (g)	Liver mass without gall bladder (g)
Mean	9.56	5.24	3.68	3.12	29.20	26.00
SD	1.27	0.79	0.83	0.34	2.17	3.39
SEM	0.57	0.35	0.37	0.15	0.97	1.52
CV	13.26	15.06	22.61	10.96	7.42	13.04
SEM%	5.93	6.74	10.11	4.90	3.32	5.83

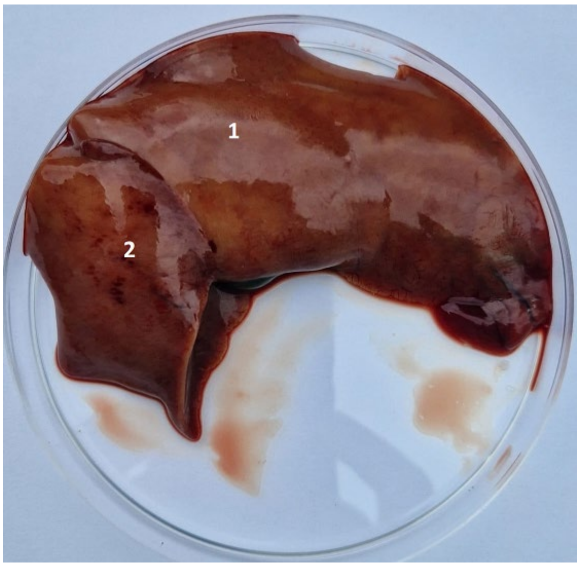


Figure 9. The liver in European catfish; 1–left lobe; 2–right lobe

The average liver mass, representing approximately 1.7% of the body mass, falls within the expected range for intensively reared carnivorous fish and is likely related to the elevated metabolic demands imposed by protein-rich diets. The presence of very limited perivisceral fat confirms that most energy reserves are stored in hepatic tissue rather than in adipose deposits.

Other organs studied from a splanchnological perspective included the spleen, kidneys, gonads, heart, and swim bladder (Figures 10-12).

Their quantitative values are presented in Table 4.

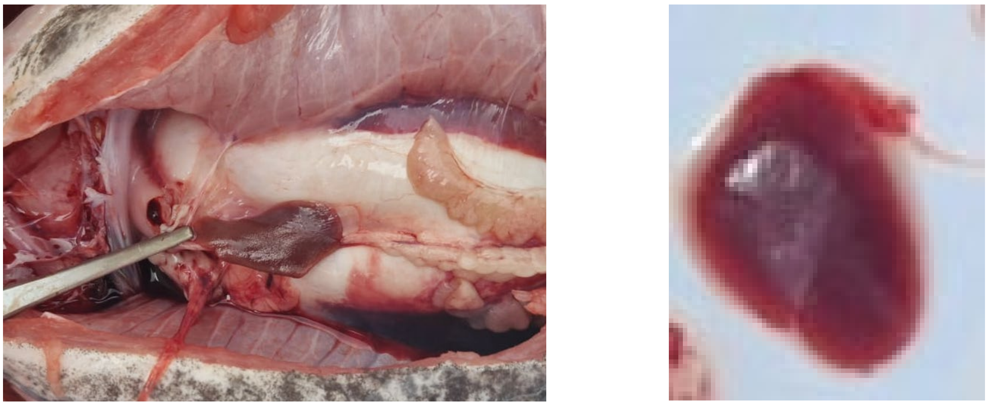


Figure 10. Spleen

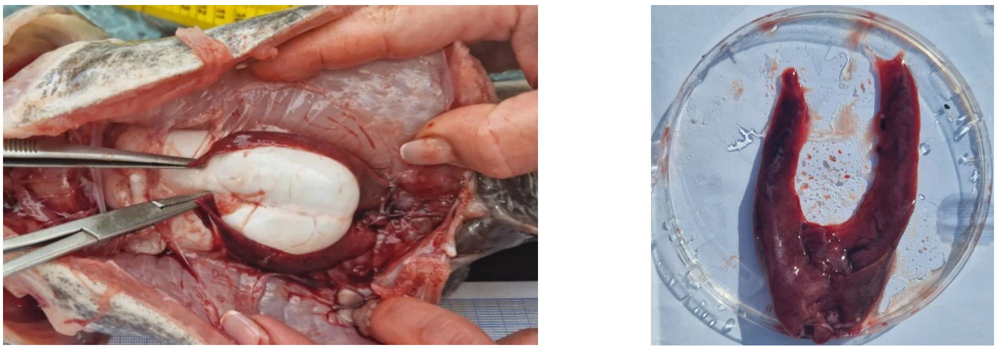
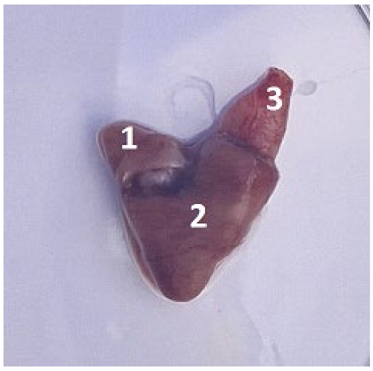


Figure 11. Kidney



a) b)

Figure 12. a) Testicles from a 2-year and 10-month-old catfish.
b) Heart of a catfish; 1–atrium; 2–ventricle; 3–arterial bulb

Table 4. Data from the quantitative splanchnology study of some organs in the abdominal cavity of European catfish (n = 5)

Specification	Spleen mass (g)	Kidney mass (g)	Kidney length (cm)	Testicles mass (g)	Heart mass (g)	Swim bladder			
						Lenth (cm)	Width (cm)	Volumetric capacity (ml)	Mass (g)
Mean	1.16	9.00	7.84	4.00	2.28	10.00	5.48	56.60	12.40
SD	0.15	2.24	1.17	1.30	0.48	1.38	0.46	12.81	4.99
SEM	0.07	1.00	0.52	0.58	0.21	0.62	0.21	5.73	2.23
CV	13.07	24.85	14.92	32.55	20.90	13.84	8.40	22.64	40.26
SEM%	5.85	11.11	6.67	14.56	9.35	6.19	3.76	10.12	18.01

These visceral organs also displayed values within expected ranges. The spleen was relatively small (1.16±0.15 g), the kidneys were moderately developed (9.00±2.24 g), while testis mass showed high variability (4.00±1.30 g), likely reflecting differences in reproductive stage. The swim bladder was well developed, with a mean capacity of 56.60±5.73 ml, providing hydrostatic support in the homogeneous water column of RAS tanks.

4. Conclusions

This study demonstrated that European catfish (*Silurus glanis*) reared in super-intensive RAS conditions exhibit favorable biometric characteristics, with good growth performance and a high slaughter yield, confirming the species' suitability for intensive aquaculture.

The splanchnological analysis revealed distinctive features of the digestive system, including a short esophagus, reduced stomach, and a relatively short intestine, which are consistent with carnivorous feeding habits but also reflect adaptations to a diet based exclusively on granulated feeds.

The presence of minimal perivisceral adipose tissue and a proportionally large liver emphasize the metabolic role of this organ in energy storage and utilization under intensive rearing conditions.

The biometric and splanchnological findings highlight the biological adaptability of *S. glanis* to controlled environments and support its economic potential as a species for modern aquaculture, where efficient growth, high carcass yield, and favorable organ proportions represent key production advantages.

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